Available online at www.sciencedirect.com
ScienceDirect
Procedia Technology 21 (2015) 611 – 618
Procedia Technology

SMART GRID Technologies, August 6-8, 2015

Comparison of Harmony Search Algorithm, Improved Harmony search algorithm with Biogeography based Optimization Algorithm for Solving Constrained Economic Load Dispatch Problems

P Karthigeyan[a*], M Senthil Raja[b],R Hariharan[c], S Prakash[d],S Delibabu[e],R Gnanaselvam[f]

[a]*Project Associate, I.I.T Madras,chennai-600036, India*
[b]*Assistant Professor, VI Institute of technology, chennai-603108,India*
[c]*PG Scholar,SRM University, chennai-603203, India*
[de]*Assistant Professor, Parisutham Institute of technology and science , Thanjavur, Tamil Nadu-613006,India*
[f]*Assistant Professor, Sri Andal alagar college of Engineering,chennai-603111,India*

Abstract

This paper presents comparison of Harmony search algorithm (HSA), improved harmony search (IHS) algorithm, Biogeography based optimization (BBO) algorithm for solving constrained economic load dispatch problems in the power system. In the IHS algorithm multiple harmony memory consideration rates and dynamic pitch adjusting rate are used to generate new solution vector..This proposed algorithms have been successfully tested in the test system which consists of twenty generating units with ramp rate limits and valve point loading constraint. The results obtained through the simulation results reveal that IHS algorithm has minimum total fuel cost and has good convergence characteristics when compared to both Harmony search algorithm and Biogeography based optimization algorithm.

Peer-review under responsibility of Amrita School of Engineering, Amrita Vishwa Vidyapeetham University

Keywords: Improved Harmony search algorithm, Harmony Search algorithm ,Biogeography based optimization algorithm ,Economic Load Dispatch, Ramp Rate limits,valve point loading constraints.

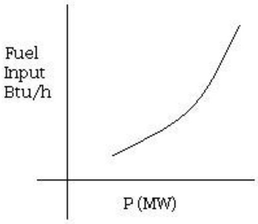
1. Introduction

Most of electrical power utilities in the world are required to ensure that electrical energy requirement from the customer is served smoothly in accordance to the respective policy of the country. Despite serving the power demands of the country, the power utility has also to ensure that the electrical power is generated within minimal

*Corresponding author. Tel.: 919003522986.
E-mail address: psiddhath627@gmail.com

Peer-review under responsibility of Amrita School of Engineering, Amrita Vishwa Vidyapeetham University
doi:10.1016/j.protcy.2015.10.071

cost. Thus, the total demand must be appropriately shared among the generating units with an objective to minimize the total generation cost for the system in order to satisfy the economic operation of the system. Economic dispatch is a procedure to determine the electrical power to be generated by the committed generating units in a power system so that the total generation cost of the system is minimized, while satisfying the load demand simultaneously**.** Economic dispatch can be defined as “The operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities”. Economic load dispatch is an important optimization task in power system operation for allocating generation among the committed units such that the constraints imposed are satisfied and the energy requirement in terms of $/hr is minimized. A simplified input-output curve of a thermal unit known as *heat rate curve* is shown in Fig. 1(a). Converting the ordinate of heat-rate curve from Btu/h to $/h results in the *fuel cost curve* shown in Fig. 1(b)



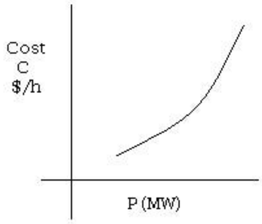


Fig. 1(a) Power Vs Fuel input Fig. 1(b) Power Vs Cost

Earlier, a number of derivatives–based approach like lambda iteration, gradient method, Lagrangian Multiplier method, dynamic programming method have been apply to solve ELD problems. But in reality input-output characteristics of modern generators are non linear because of valve point effect, ramp rate constraints and so on. Recently heuristics optimization techniques such as genetic algorithm(GA),particle swarm optimization (PSO), artificial bee colony(ABC) have been successfully applied to solve ELD problem with non-smooth cost functions. One such recent technique is Harmony search algorithm. Harmony search (HS) algorithm has been recently developed in an analogy with improvisation process where musicians always try to polish their pitches to obtain a better harmony. Music improvisation process is similar to the optimum design process which seeks to find optimum solution. The pitch of each musical instrument determines the certain quality of harmony, just like the objective function assigned to the set of variables. An improved version of HS algorithm is called Improved Harmony Search Algorithm. This paper deals with the IHS algorithm used to solve ELD problem with inclusion of Ramp Rate limits.

2. Problem Formulation

The main objective of economic load dispatch $problem\ is\ to\ minimize$

$$\min f = \sum_{i=1}^{N} F_i(P_i) \qquad (1)$$

Where $F_i$is the total fuel cost for the generator unity i (in $\$/h$), which is defined by equation:

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i(2) \qquad (2)$$

Where a_i,$b_i$and $c_i$are cost coefficients of generator i. Two constraints are considered in this problem, i.e., the generation capacity of each generator and the power balance of the entire power system.

*Constraint 1***:** This constraint is an inequality constraint for each generator. For normal system operations, real power output of each generator is within its lower and upper bounds and is known as generation capacity constraint given by

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \quad (3)$$

Constraint 2: This constraint is an equality constraint. In which the equilibrium is met when the total power generation must equals the total demand P_D and the real power loss in transmission lines P_L. This is known as power balance constraint can be expressed as given in

$$\sum_{i=1}^{N} P_G = P_D + P_L \quad (4)$$

Ramp rate limit constraint: The power generated, $Pi0$ by the ith generator in certain interval may not exceed that of previous interval $Pi0$ by more than a certain amount URi, the up-ramp rate limit and neither may it be less than that of the previous interval by more than some amount D$Ri$the down ramp rate limit of the generator .These give rise to the following constraints.

As generation increases

$$P_i - P_{i0} \leq UR_i$$

As generation decreases

$$P_{i0} - P_i \leq DR_i$$

and

$$max(P_i^{min}, P_{i0} - DR_i) \leq P_i \leq \min(P_i^{max}, P_{i0} + UR_i) \quad (5)$$

Valve point loading constraint:

The valve-point loading is taken in consideration by adding a sine component to the cost of the generating units. Typically, the fuel cost function of the generating units with valve-point loadings is represented in Fig.2.

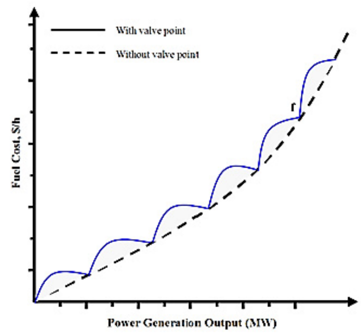


Fig. 2 Power generation output Vs Fuel cost

3. **Harmony Search Algorithm**

The harmony search (HS) algorithm, proposed by Geem, is a nature inspired algorithm, mimicking the improvisation of music players. The harmony in music is analogous to the optimization solution vector, and the musician's improvisations are analogous to the local and global search schemes in optimization techniques. The HS algorithm uses a stochastic random search, instead of a gradient search. This algorithm uses harmony memory considering rate and pitch adjustment rate for finding the solution vector in the search space. The HS algorithm uses the concept, how aesthetic estimation helps to find the perfect state of harmony, to determine the optimum value of the objective function. The HS algorithm is simple in concept, few in parameters and easy in implementation. It has been successfully applied to various optimization problems. The optimization procedure of the HS algorithm is as follows:

1) Initialize the optimization problem and algorithm parameters.
2) Initialize the harmony memory.
3) Improvisation of a New Harmony memory.

4) Update the harmony memory.
5) Check for stopping criteria. Otherwise, repeat step 3 to 4

Fig. 3 shows the block diagram of Harmony Search Algorithm.
.

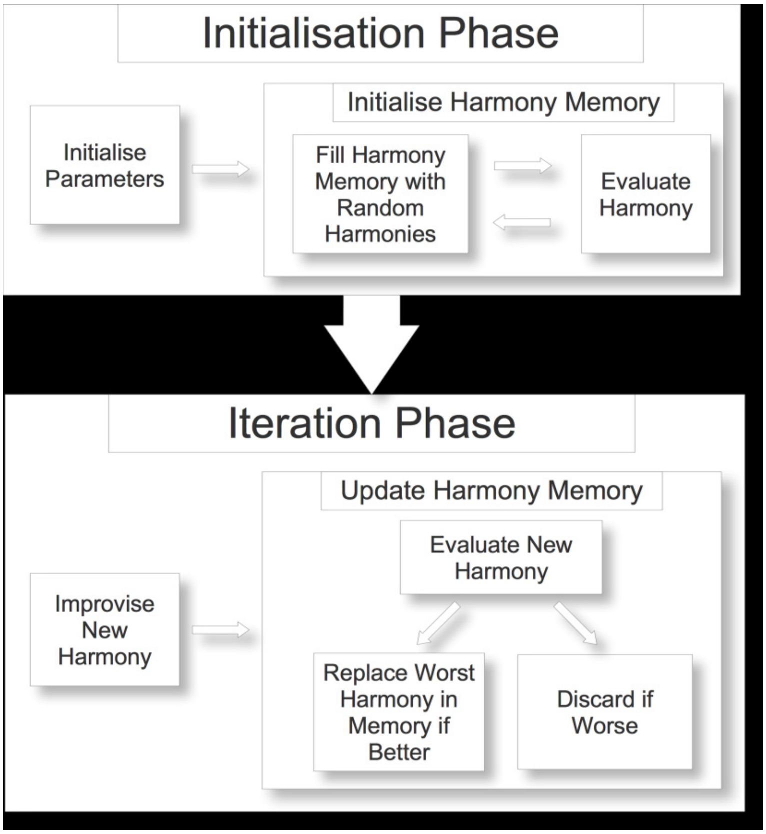


Fig. 3: Block Diagram of Harmony search Algorithm

4. Implementation of the Proposed Approach

The proposed approach to solve ELD problem is described in the following steps.

1) Input the system parameters, minimum and maximum limits of control variables.

2) Choose the harmony memory size HMS, pitch adjusting rate PAR, bandwidth BW and the maximum number of improvisations NI.

3) Initialize the harmony memory HM as explained in the section III-B. While initializing, all the control variables are randomly generated within their limits.

4) Start the improvisation.

5) For each solution vector in HM, evaluate the objective functions.

6) Improvise the New Harmony memory as explained in the section III-C.

Table 1 : Comparison of fuel cost coefficients for different generators

No.of Generators	P_{min} (MW)	P_{max} (MW)	A ($/MWhr)	B ($/MWhr)	C ($/MWhr)
1	50.0	300	95	6.8000	0.0070
2	50.0	450	30	4.0000	0.0055
3	50.0	450	45	4.0000	0.0055
4	0.0	100	10	0.8500	0.0025
5	50.0	300	20	4.6000	0.0060
6	50.0	450	90	4.0000	0.0055
7	50.0	200	42	4.7000	0.0065
8	50.0	500	46	5.0000	0.0075
9	0.0	600	55	6.0000	0.0085
10	0.0	100	58	0.5000	0.0020
11	50.0	150	65	1.6000	0.0045
12	0.0	50	78	0.8500	0.0025
13	50.0	300	75	1.8000	0.0050
14	0.0	150	85	1.6000	0.0045
15	0.0	500	80	4.7000	0.0065
16	50.0	150	90	1.4000	0.0045
17	0.0	100	10	0.8500	0.0025
18	50.0	300	25	1.6000	0.0045
19	100.0	600	90	5.5000	0.0080
20	120.0	500	18	6.7000	0.0020

7) Perform the non-dominated sorting and ranking on the combined existing and New Harmony memory

8) Choose the best harmony memory from the combined solution vectors as given in the section III-D for the next

Table 2 : Comparison of BBO, HS, IHS with ramp rate limit

LOAD DEMAND(MW)	BBO TOTAL COST($/hr)	HSA TOTAL COST($/hr)	IHSA TOTAL COST($/hr)
925	1232.90	1020.56	846.324
1000	1438.00	1120.12	989.94
1500	2487.52	2332.41	2234.32
2000	4257.37	4167.8	3979.26
2500	6477.52	6421.93	6224.65

improvisation.

9) Check for stopping conditions. If the number of improvisations has been reached stop the algorithm. Otherwise, go to step 5.

5. Biogeography Based Optimisation Algorithm

BBO, suggested by Dan Simon in 2008, is a stochastic optimization technique for solving multimodal optimization problems. It is based on the concept of biogeography, which deals with the distribution of species that depend on different factors such as rain fall, diversity etc.The main parts of BBO algorithm includes

- Migration
- Mutation

BBO STEPS:
The algorithm steps of BBO are as follows

Step 1: Initialization of the BBO parameters.
Step 2: The initial position of SIV of each habitat should be randomly selected while satisfying different equality and inequality constraints of ELD problems. Several numbers of habitats depending upon the population size are being generated. Each habitat represents a potential solution to the given problem.
Step 3: Calculate each HSI i.e. value of objective function for each i-th habitat of the population set n for given emigration rate μs, immigration rate λs and species S.
Step 4: Based on the HSI values some elite habitats are identified.
Step 5: Each non-elite habitat is modified by performing probabilistically immigration and emigration operation.
Step 6: Species count probability of each habitat is updated using equation11. Mutation operation is performed on the non-elite habitat and HSI value of each new habitat is computed.
Step 7: Feasibility of a problem solution is verified i.e. each SIV should satisfy equality and inequality constraints.
Step 8: Go to step 3 for the next iteration.
Step 9: Stop iterations after a predefined number of iterations.

5. Simulation Results

Fuel cost coefficients and generation limits for each generating unit of the 20 generator test system are given in Table 1. The simulation results gives the comparison of Harmony Search algorithm (HSA), improved harmony search algorithm (IHSA), Biogeography based optimization algorithm (BBO) and the results obtained are shown in Table 2. Table 3 shows the comparison of the results with respect to valve point loading.

Table 3 : Comparison of BBO, HSA, IHS with valve point loading

LOAD DEMAND(MW)	BBO TOTAL COST($/hr)	HS TOTAL COST($/hr)	IHS TOTAL COST($/hr)
925	872.425	838.14	687.79
1000	1036.84	1016.54	976.98
1500	2266.82	2157.54	1004.87
2000	4016.83	3354.98	2900.889
2500	6266.83	5735	4089.13

RAMP RATE CONSTRAINT:

The convergence characteristics obtained for all the three algorithms with the inclusion of ramp rate limit costraint is shown in Fig. 4. The comparison of fuel cost with ramp rate is shown in Fig. 5.

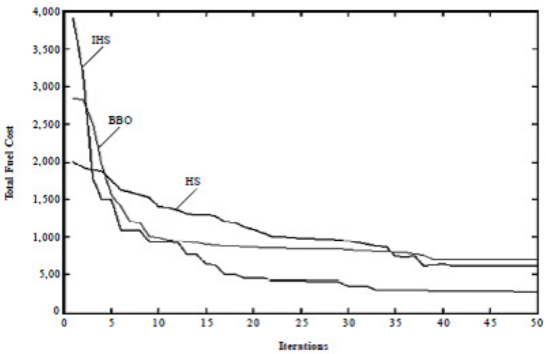


Fig. 4 Convergent characteristic of all algorithms

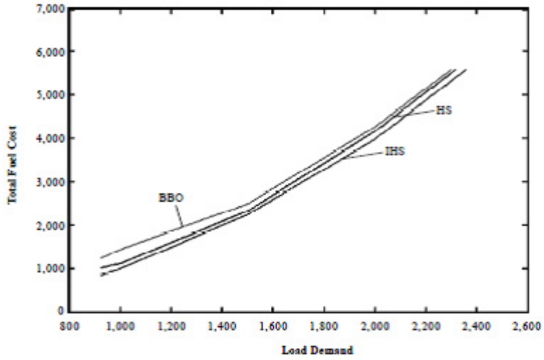


Fig 5 Comparison of Fuel Cost Solution

VALVE POINT LOADING CONSTRAINT:

The convergence characteristics obtained for all the three algorithms with the inclusion of valve point loading constraint is shown in Fig. 6. The comparison of fuel cost with valve point loading is shown in Fig. 7.

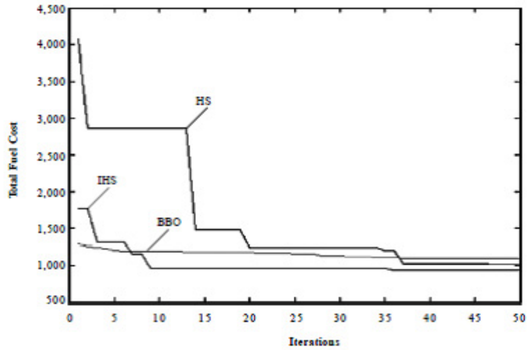


Fig. 6 Convergence Characteristics Between IHS, HS, BBO with Valve point loading

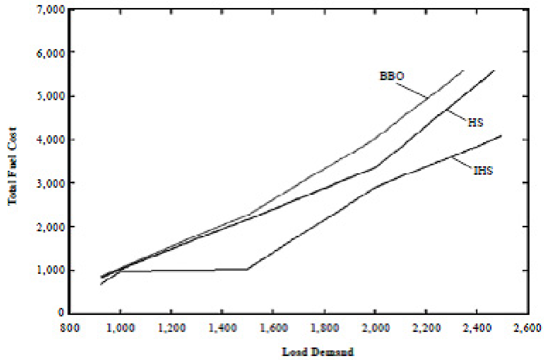


Fig. 7 Comparison of fuel cost from the table with valve point loading

6. Conclusion

The economic load dispatch problem is solved by using IMPROVED HARMONY SEARCH ALGORITHM (IHS), HARMONY SEARCH ALGORITHM (HSA), BIOGEOGRAPHY BASED OPTIMISATON ALGORITHM (BBO) in the power system with the inclusion of ramp rate limit constraint, valve point constraint for 20 generating units. From the simulation results the performance of IHS algorithm is better and giving minimum total fuel cost when compared to both HS and BBO algorithms. Although HS algorithm might be known but comparing with BBO and IHS under constraints of ram prate and valve point loading to improve the fuel cost is said to be novel and inventive.

The Improved Harmony Search algorithm is better when compared to other algorithms because of two reasons.

- Total fuel cost is minimum when compared to others.
- Convergence characteristics response is fast when compared to others.

References

[1] Leandro dos Santos Coelho, Viviana Cocco Mariani, An improved harmony search algorithm for power economic load dispatch, Energy Conversion and Management ,Elsevier, 50 (2009), p. 2522–2526, May 2009.

[2]M. Mahdavi, M. Fesanghary, E. Damangir, An Improved Harmony Search Algorithm for Solving Optimization Problems, Elsevier, Applied Mathematics and Computation, Vol. 188, p. 1567-1579, 2007.

[3] Geem ZW, Kim JH, Loganathan GV, A new heuristic optimization algorithm: Harmony search. Simulation 2001; **76**: 60-68.

[4] Hadi Sadat, “Power System Analysis”, WCB/McGraw-Hill, 1999.

[5] D.P. Kothari and J.S. Dhillon, Power System Optimization, Prentice-Hall of India, 2006.

[7] Lee KS, Geem ZW. A new meta-heuristic algorithm for continuous engineering optimization: harmony search theory and practice. Elsevier, Computational Methods Appl. Mech. Eng 2005; 194(36–38):p.3902–33.

[8] J. Mahdavi M, Fesanghary M and Damangir E (2007), An Improved Harmony Search Algorithm for Solving Optimization Problems, Elsevier, Applied Mathematics and Computation, Vol. 188, p. 1567-1579.

[9] Bhattacharya, P.K. Chattopadhyay, Biogeography-based optimization for different economic load dispatch problems, IEEE Trans. on Power Systems, Vol. 25, p. 1064- 1077, May 2010.

[10] L.D.S. Coelho, V.C. Mariani, Combining of chaotic differential evolution and quadratic programming for economic dispatch optimization with valve point effect, IEEE Trans. on Power Systems, Vol. 21, p. 989–996, May 2006.